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Quarterly Technical Summary

General Research

15 August 1969

Prepared under Electronic Systems Division Contract AF 19(628)-5167 by

Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Lexington, Massachusetts



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Issued 18 September 1969

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## INTRODUCTION

This Quarterly Technical Summary covers the period from 1 May through 31 July 1969. It consolidates the reports of Division 2 (Data Systems), Division 4 (Radar), Division 5 (Optics), Division 7 (Engineering), and Division 8 (Solid State) on the General Research Program at Lincoln Laboratory.

Accepted for the Air Force  
Franklin C. Hudson  
Chief, Lincoln Laboratory Office

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## DATA SYSTEMS DIVISION 2

### INTRODUCTION

This section of the report reviews progress during the period 1 May through 31 July 1969 for the General Research Program of Division 2. Separate progress reports on Graphics and Seismic Discrimination describe other work in the Division.

F. C. Frick  
Head, Division 2

M. A. Herlin  
Associate Head



# DIVISION 2 REPORTS ON GENERAL RESEARCH

15 May through 15 August 1969

## PUBLISHED REPORTS

<u>Journal Articles*</u>			
JA No.			
3257	A Map of M-42 and M-43 at a Wavelength of 1.94 cm	M. A. Gordon	Australian J. Phys. <u>22</u> , 201 (1969)
3362	Theory and Practice of Ionosphere Study by Thomson Scatter Radar	J. V. Evans	Proc. IEEE <u>57</u> , 496 (1969)
3493	Water Vapor: Observations of Galactic Sources	M. L. Meeks J. C. Carter A. H. Barrett† P. R. Schwartz† J. W. Waters† W. E. Brown, III†	Science <u>165</u> , 180 (1969)
MS-2444	Radar Surveys of the Solar System	J. V. Evans	Proc. Am. Phil. Soc. <u>113</u> , 203 (1969)

## UNPUBLISHED REPORTS

<u>Journal Articles</u>			
JA No.			
3376	A Radar Study of the HII Region Orion B	M. A. Gordon	Accepted by Astrophysical Journal
3465	The Strange Story of the OH Molecule in Interstellar Space	J. M. Moran	Accepted by Science Journal
<u>Meeting Speeches‡</u>			
MS No.			
2507C	Computer Assisted Integrated Circuit Photomask Layout	F. K. Richardson	Seminar, University of Arkansas, 26 June 1969
2585	A Microprogrammed Digital Vocoder Analyzer	E. I. Ancona	IEEE Workshop on Computer Arithmetic, Minneapolis, 16 June 1969
2624	Circuit Simulation Present and Future	H. B. Lee	WESCON/69, San Francisco, 19-22 August 1969

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\* Reprints available.

† Author not at Lincoln Laboratory.

‡ Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

## SURVEILLANCE TECHNIQUES

### GROUP 21

#### I. SUMMARY

Group 21 operates and maintains the Millstone Radar and Haystack Research facilities of the Laboratory's Millstone Hill Field Station. The Group also conducts a program in Radio Physics in which the emphasis at Haystack is on planetary radar and radiometric techniques, while at Millstone ionospheric and radar propagation studies related to precision tracking techniques are carried on.

At Millstone, the instrumentation phase of the ABMDA radar propagation program is continuing along with auroral data gathering. The Thomson scatter research has involved thesis work of three students who are interpreting and publishing results from the radar measurements.

The work at Haystack has yielded, among many things, new topographic and cross-section data on Mars which is being compared with optical data to obtain an improved understanding of the planet's surface. NASA supports the Mars effort and the 3-cm lunar mapping project, the data-gathering and processing phase of which is nearing completion. These two projects are reported in detail in Lincoln Laboratory Quarterly Progress Reports entitled, "Radar Studies of the Moon and Mars," the most recent of which was dated 15 July 1969.

Radiometric work has emphasized observations of newly discovered sources of water-vapor emission at 22.235 GHz and the engineering and construction effort involved in establishing a very long baseline interferometer between Haystack, NRAO (Green Bank, West Virginia) and Owens Valley (California).

#### II. SPACE SURVEILLANCE TECHNIQUES

The bulk of the work in this area is related to studies of propagation and clutter effects on precision radar tracking. This work, supported by the Army Advanced Ballistic Missile Defense Agency, is reported separately in semiannual reports to ABMDA. Target tracking operations have also provided real-time pointing data and radar cross-section measurements in support of the optical and IR sensor research program conducted by the Optics Division (Division 5) at the Firepond Research Facility at Millstone Hill.

A UHF beacon tracking system is being incorporated into the Millstone 84-foot tracking radar for the ABMDA propagation study program. Software has been developed for the computer-automated acquisition of monopulse calibration data from radioastronomical sources. This technique should find application in calibrating other precision radar systems.

Data recovery and analysis of the auroral backscatter observations made in April-May 1969 are proceeding. A correction procedure has been formulated for removing instrumental effects from the auroral spectra detected with the matched filter system of the real-time spectrum analyzer. Computer programs have been prepared to display the spatial and temporal behavior of the echo amplitude and spectrum.

### III. HAYSTACK PLANETARY RADAR

#### A. System Development

The preceding quarterly period terminated with the X-band transmitter performing well at 320 kW. In late May, however, one of the high-power klystrons began to malfunction, resulting in operations restricted to 200-kW output until the Planetary Radar Box was removed from the antenna on 8 July. The PR Box was restored to the antenna on 21 July after a klystron change (back to Serial No. 1) which restored power to the 300-kW level.

#### B. Planetary Studies

##### 1. Mars

During the favorable period surrounding the 31 May 1969 opposition, the planet Mars is being observed with the Haystack radar to improve the available knowledge of the topography in a belt near the equator. Data gathering began on 7 May and will continue so long as we have a favorable signal-to-noise ratio.

Preliminary results show that the topography along a strip extending from 5°N to 12°N in latitude is well correlated with that measured for a latitude of 22°N during the 1967 opposition. However, there are some differences, the most notable of which is a region around 220° in longitude (close to Elysium) which showed up as a highland at 22°N but failed to do so at 5°N.

Measurements of cross section confirm that the optically dark regions have relatively high radar reflectivity. Estimates of the rms variation in the distribution of slopes obtained by fitting to a theoretical law indicate a wide variation with longitude. Generally, regions of high cross section appear smooth. Measurements in the region known as Syrtis Major give an rms slope of less than 2°, compared with an average of 3° for the rest of the planet's surface.

##### 2. Venus and Mercury

Throughout this reporting period, we continued to accumulate ranging data on the planet Venus, primarily for improving the accuracy of the Fourth Test of General Relativity. The higher resolution (short baud length) ranging measurements were reluctantly canceled because of the poor signal-to-noise ratio resulting from the above-mentioned limited power capability and the increasing range of the planet.

The range-Doppler data from the Fourth Test measurements have also been examined to obtain a crude height profile on Venus. The examination apparently revealed a feature some 50 miles wide rising about  $1\frac{1}{2}$  miles above the surrounding regions, but the data must be studied further to confirm this.

Spectral measurements were also emphasized and the data permitted a much smoother plot of the reflectivity vs longitude of the planet. The most satisfying result has been the confirmation of an area of high reflectivity first observed in 1966, but with poor signal-to-noise ratio. This area, not visible during closest approach, has a cross-section value twice the average value normally observed (3.4 percent as opposed to 1.7 percent of geometric).

Mercury continues to be an elusive target. The combination of equipment problems and rainy days has severely reduced the amount of data acquired. The planet has been near its greatest distance, and the stacking of six or more runs is required to produce a valid signal.

### C. Lunar Studies

Radar mapping, in both polarizations, of the earth-visible hemisphere of the Moon is essentially complete. In general terms, the radar data can be interpreted to give local values of surface roughness (on a 4-cm scale) and surface tilt, with a resolution of about 2 km. This information comes from a comparison of expected- and cross-polarized returns, taking into account the differing ratios of backscattered power for the two polarizations, both with local angle of incidence and also with local roughness.

Local areas of enhanced roughness (using the above interpretation of the data) appear profusely on the surface, most often as circular fields either surrounding a sharply defined ("new") crater or else superimposed upon one of the ray-systems that appear on optical photographs of the same area. The ray-contained enhancements, however, are almost always relatively much brighter than the rays themselves at radar wavelengths, as compared with optical wavelengths. The rays themselves, in fact, quite often are difficult to discern at all on the radar maps, whereas the superimposed enhancements are from two to five times brighter than their surroundings. We might then conclude that the rays consist of a fine-grained material strewn for several hundred kilometers along the surface, with concentrated clumps of coarser material scattered randomly along the same paths.

As another analysis project, a portion of the data is being used to generate a height profile map of the central 20° cap of the moon. It is expected that an absolute-height precision of better than 1 km above a 1738-km sphere will be achieved.

## IV. THOMSON SCATTER

We have continued to make observations at a rate of two UHF (24-hour long) and two L-band (12-hour long) measurements per calendar month. In conjunction with I. Gastman (University of Michigan), a short report has been written on the observation of conjugate photoelectrons last spring by measuring the intensity of the "plasma lines." A second report has been written with L. Carpenter (University of Illinois) describing the measurements now in progress of ionospheric vertical drifts and the accuracy achieved in these measurements.

An M.I.T. undergraduate, L. P. Cox, undertook an analysis of the L-band data obtained since 1965 for his baccalaureate thesis. As discovered in an earlier study, a seasonal variation in the relative abundance of atomic and molecular ions in the F1 region was observed. A note summarizing this work has been prepared for publication. A more refined analysis, using only data taken with the new spectrum analyzer, is in progress. This work is expected to yield the seasonal variations in the densities of the neutral particles near 200 km that give rise to the observed ion composition changes.

## V. RADIOMETRIC TECHNIQUES

### A. Instrumentation at Haystack

Installation of the 22.235-GHz water-vapor radiometer in the Planetary Radar Box was completed on schedule in early June. Its feedhorn is mounted off-axis, to one side of the radar feedhorn. The feed output is mixed down to a 63.5-MHz IF which, after amplification, is sent to the control room and the autocorrelator spectral line system. Local oscillator power comes from



## Division 2

the third harmonic of a 7.4-GHz klystron oscillator phase locked to the station's frequency standard. Since its installation, this radiometer has been used every weekend that the PR Box was on the antenna.

Every radiometer in the Radiometry Box was used while it was on the antenna for two weeks in July, and no equipment problems occurred. No major additions to the R-Box system were made during this quarter, but plans were made for improvements later this year. These include the temporary installation of parametric amplifiers at 22.2 and 23.7 GHz, and a spectral line radiometer at 9.9 GHz built by the Research Laboratory of Electronics at M.I.T.

### B. Radio Astronomy

The establishment of an agreement between Northeast Radio Observatory Corporation (NEROC) and Lincoln Laboratory, which facilitates arrangements for work at Haystack by academic personnel, has resulted in the submission of many new proposals for research. If supplementary support is received through NERO, scheduling of most of these proposals will be possible. Many have already been approved and scheduled.

Work is currently under way on planning and building equipment for a three-station VLBI (Very Long Baseline Interferometer) between Haystack, the NRAO 140-foot telescope, and a 90-foot antenna at Owens Valley Radio Observatory in California. The main purpose of the experiment is to measure the gravitational deflection of the radio source 3C279 as it approaches the limb of the sun during the first two weeks of October. It is also hoped that the experiment will yield information on the earth's polar wobble and provide accurate measures of the interferometer baselines.

This experiment is the joint effort of members of Lincoln Laboratory, the M.I.T. campus, and NASA Goddard. A project group with members from all three organizations has been established under the direction of a Haystack staff member.

The experiment to measure the frequency of UHF transitions of SH continues. This experiment is partially supported by Group 76 (Environmental Test Laboratory) and is being conducted jointly with H. E. Radford of the National Bureau of Standards. The method consists of manufacturing SH inside of an evacuated cylindrical resonant cavity, and then measuring the RF transmission through the cavity as a function of frequency. To achieve the necessary sensitivity, some kind of modulation scheme is necessary. As reported in the previous Quarterly Technical Summary, the gas ionized at the electric potentials required for modulation by Stark effect. During this quarter, the experiment was undertaken using Zeeman (magnetic) modulation; this attempt was also unsuccessful.

At Haystack, we have continued to monitor the newly discovered sources of water-vapor emission at 22.235 GHz in order to observe the nature of the time variations in the emission. Measurements during the preceding quarterly period showed unmistakable variations in time intervals as short as one week. Hence, we undertook a program of weekly measurements on the following sources: W3 (OH), W3 (Continuum), W49, W51, W75, Sgr B2, and the Orion Nebula. We hope that these measurements will allow us to characterize the processes that give rise to H<sub>2</sub>O emission with the maser-like character that is observed.

We have searched for polarization, both circular and linear, in the water-vapor emission, and we find linear polarization in W3 (OH), W49, Sgr B2, and the Orion Nebula. But no circular polarization was detected in any source.



Two VLBI experiments were performed on the most intense  $H_2O$  sources to establish whether or not these sources have very small angular size. These experiments, performed with a 12-foot antenna on the M.I.T. campus and with the 85-foot antenna of the Naval Research Laboratory at Maryland Point, Maryland, were made during the last three weeks of this quarter, and data from Haystack and the two sites have not yet been processed. This research is being conducted jointly with Professor B. F. Burke and associates on the M.I.T. campus, and with the Naval Research Laboratory.

For a period of 15 hours on 17-18 July, we observed OH emission sources with the Haystack antenna as a part of a VLBI experiment with the 84-foot antenna of Chalmers Institute of Technology, Onsala, Sweden. Data from this experiment will be processed in Sweden.

Planning began for millimeter-wave mapping of the sun in support of research in solar activity and prediction methods being conducted at the Air Force Cambridge Research Laboratories.

## DIGITAL COMPUTERS GROUP 23

### I. CIRCUIT AND NEW MACHINE DEVELOPMENT

#### A. Semiconductor Processing

Results obtained with the 5- and 10-mW gate chains led to the selection of the 5-mW configuration as the standard cell for our first integrated gate array. An 80-gate array has been designed on a  $120 \times 130$  mil chip. Sixteen bias generators are also included on the chip.

Three devices will employ this basic gate array, differing only in the structure of the interconnection metal. The first, which is now undergoing semiconductor processing, consists of a series of gate chains with multiple fan-in and fan-out loading. This will provide useful information on processing and on loaded circuit performance. The second is a prototype adder which is in the final stages of mask design. The third device will be a  $2 \times 2$  multiplier.

A simple three-input gate was designed and fabricated using the mask program and the collector diffused isolation (CDI) process. Initial yields were very good. A wire-bonded delay chain produced stage delays of about 2 nsec. A new chip, similar to the 5- and 10-mW delay chains (SMX-14) previously made with the standard process, will be fabricated with the CDI process to provide a better comparison of the two. The CDI process has fewer fabrication steps and uses less area than the standard process.

Packaged Read-Only Memory devices have been programmed by scribing a photoresist layer and etching the metal below. Evaluation of the ROM performance will continue.

#### B. Device Evaluation

The CDI test transistors show excellent performance at high currents due to their inherent low collector series resistance. A device with  $0.1 \times 0.3$  mil base and emitter stripes made with the normal process will show considerable  $f_T$  falloff at 1.5 mA. The CDI transistor will operate as well out to 65 mA.

#### C. Interconnection of Integrated Circuits

A new method for the selective formation of insulating films is being investigated. Thin layers of polyester resin, up to several mils thick, can be selectively irradiated with short-wavelength ultraviolet light through evaporated and photoetched metal masks on quartz, to yield a pattern of crosslinked and uncrosslinked resin, the latter being removable by means of a solvent spray. Experimental work indicates that such selectively exposed polyester resin layers may be used as insulation over arrays of cast-in-place integrated circuit chips, the unexposed and developed areas forming vias through which metalization of exposed chip conductors can be achieved.

Currently,  $2 \times 2$  arrays of 35-mil square integrated circuit chips are being assembled in silica-loaded polyester resin on copper substrates. Approximately 1-mil thick selectively crosslinked polyester resin layers, with vias as small as 2 mils square, are formed over the

chips and then electroless nickel-on-aluminum depositions are made in the opened vias. Conventional electroless copper deposition and photoetching produces the chip-interconnection wiring. The process should be extendable to multilayer wiring.

#### D. LX-1 Microprocessor

A series of in-depth review meetings have been held to survey the present design of the MECL Microprocessor and the potential applications. In the applications that were studied, it was found both necessary and desirable to have the ability to multiply at a faster rate than possible with a software multiply subroutine; therefore, a multiply function box will be added to the basic machine. This box will be designed using MECL II and/or III circuits. The MECL multiplier will be  $16 \times 16$  and will generate a 32-bit result in approximately 200 nsec. It is expected that it will be replaced eventually by a prototype LSI multiply array currently under development.

#### E. Testing Computer

Hardware and software have been completed which link the testing computer to the TX-2 via a 150-baud data set interface. The testing computer resembles a remote teletype console to the TX-2 time-sharing system.

The general-purpose hardware for connecting the testing computer to test equipment consists of 15 double-rank 16-bit registers, 16 individually addressable flip-flops, and control hardware. This module has been completed and checked out. The additional hardware necessary for one particular application, the testing of Read-Only Memories, is being designed.

A demand paging system has been implemented which makes it possible to directly address 65K words of memory, although no more than 8K words are actually in core at any one time. If a word which is not in core is referenced, a hardware interrupt will cause execution of a program which will bring the desired page in from the disk. A fixed priority multiprogrammed executive has been implemented to run within the paging system.

Single-line editing facilities, similar to those of the Berkeley CAL system, and a debug package which allows register interrogation and modification have been implemented to run under the multiprogrammed executive. Arithmetic, exponential, and trigonometric subroutines which operate on 40-bit floating-point numbers have been implemented and are being fitted into the paging system.

## II. MAGNETIC FILM ENGINEERING

#### A. Sensing

Coupling networks (between digit lines, sense amplifier, and digit driver) that are simpler than those used in LCM I have been studied. It has been found that the improvement in signal-random noise obtained with a  $n:1$  step-up transformer before the first amplifier stage can be obtained without the transformer if the first stage consists of  $n^2$  transistors in parallel. Such a design is highly compatible with integration. However, transformerless sense amplifiers still have signal/random noise inferior to transformer-coupled amplifiers. The transformer bridge circuits that isolate the amplifier from digit drive must be replaced by a transistor bridge whose extra transistors enhance noise.

## Division 2

### B. Word Lines

Installation of a precision substrate indexing unit and the generation of a new exposure master have greatly reduced the line-to-pad alignment errors. Use of plastic-coated, anodized aluminum for substrates is being investigated. The anodic layer provides a hard, insulating base, with the plastic overcoat acting to smooth the surface. Initial tests have demonstrated scribing feasibility and insulation integrity, but the magnetic characteristics indicated excessive surface roughness. Smoother substrates are being made in an attempt to achieve acceptable magnetic properties.

### C. Digit Lines

The large scribing machine remains unfinished due to a 6-week delay in delivery of a main rail. The deposition fixture for holding eight  $52 \times 2.2$ -inch glass digit substrates is complete. Washing tanks for these substrates are being fabricated and the "float glass" substrates have been received. Further work with carbonyl iron keeper on metal substrates has been abandoned due to high noise caused by internal voids in the keeper and inadequate flatness of the conductor-keeper laminate.

### D. Magnetic Film Plating

Four-layer closure films (Cu-Co-Ni-Co) are being plated on word lines to yield memory bits with the predicted improvements due to closure. In spite of extensive precautions, numerous filamentary shorts exist across the  $\frac{1}{4}$ -mil space between lines; these may, however, be burned out without much danger to the lines themselves.

## III. COMPUTER SYSTEMS

### A. Display

#### 1. Character Generator

The new character generator based on the TX-2 conic generator techniques has been built and bench tested, and meets the specifications satisfactorily. One of the features of this generator is to compensate automatically for the bandwidths of different CRT deflection systems; this compensation works well. Clearly legible characters are produced in 10 to 15  $\mu$ sec on CRT with bandwidth of only 200 kHz. What remains to be done is to design the stroke data for individual characters; a TX-2 program has been written for this. After the data for all the characters are collected, a Read-Only Memory will be ordered and interfaced to the stroke generator.

#### 2. Box Generator

The compensation technique used in the character generator has also been incorporated in a rectangle (or box) generator for the TX-2 Sequence 64 display. The motive for the box generator is the Mask Design program where large numbers of rectangles are displayed. Presently, these rectangles are generated as individual line segments, thus using a large amount of memory as well as being slow. The box generator should reduce the memory requirement and improve the drawing speed by nearly an order of magnitude.

### 3. Storage Scopes

In order to relieve the loading of the TX-2 display generator, work has been progressing to use the storage scopes for relatively static displays. A public program has been written to display text files; its performance is satisfactory even under moderately heavy time-sharing load.

Work is also progressing on a text editor for storage scopes. Since the current scope editor changes the display for every key typed, a completely new editor design has been developed.

#### B. Video Raster Printer

A new experimental printer which will produce hardcopy using a Xerox LDX Printer (Receiver) is being designed. The LDX Printer will be driven by a DEC PDP8/L computer. Printing formats (including character fonts and graphs) will be determined solely by software and will not be hardware constrained as in the present Xerox Charactron Printer. The hardcopy will be 8.5 inches wide and will be produced at 1.6 inches per second ( $8.7 - 8\frac{1}{2} \times 11$  pages per minute).

Functional characteristics of the PDP8/L to LDX Printer interface have been specified. There are still a few outstanding unanswered questions about LDX timing, synchronization and paper feed, but sufficient information has been gathered so that the detail logic design can proceed. The sequence switch and plug-in units for the new sequence are under construction.



## PSYCHOLOGY GROUP 25

### I. PROVISIONS FOR MAN-MACHINE INTERACTION ON THE IBM 360/67

#### A. Mediator

The Mediator augments the current operating system, CMS (Cambridge Monitor System); it provides several automatic program services for the user, as outlined in the Quarterly Technical Summary dated 15 May 1969. This reporting period has been concerned with testing the operation of the Mediator, correcting a number of minor flaws, and doing a series of house-keeping chores needed to make it "public" on the Laboratory computing facility. As a first step, the Computer Systems group (Group 28) has made it possible to link the disk area of any user account in a read-only manner to the area with Mediator programs. Also, a public executive routine is provided so that linking to the Mediator is automatic when the command MEDIATE is given in CMS. This makes the Mediator, as well as its associated directory and library of Reckoner and utility programs, a "public" system.

Making the system useful, as well as available, requires documentation. A reference manual for Mediator programmers, including definition of calls to the Mediator, is nearly finished. A guide for Fortran programmers is being prepared which contains a description of a set of sub-routines called Studs. (Collectively, the Studs embody a particular set of linguistic and operating conventions within which to run Fortran-compiled programs.) When this documentation is complete, the Mediator will be ready as a new facility for writing and running programs in coherent libraries.

#### B. Reckoner

The main effort on the library of Reckoner programs has been on correcting programming errors and documentation. There are two documents: one is a Reference Book which provides a detailed description of each program in the current library; the other is a 10-page Reckoner User's Guide, an attempt to present most of the information needed by a novice Reckoner user to carry out large-scale and complex calculations. Currently, the Reckoner can be accessed by giving the CMS command MEDIATE. The user is linked automatically to the Mediator, and the directory and library of public programs. This library currently has as its main component the set of routines that constitute the Reckoner.

The obvious reason for making the Reckoner public is to permit staff scientists and engineers to compile private files of data, access data banks, and calculate on the numbers in a very general way. The Reckoner is a new and potentially very useful service to Laboratory scientists and engineers, but its practical utility will depend critically on the manner in which the operating system on the IBM 360/67 computer is able to support it.

### II. PROVISIONS FOR MAN-MACHINE INTERACTION ON TX-2

A major revision of the Apex scheduling algorithm has been completed. Tasks which require a large amount of core storage and processor time now are segregated in a "background

round robin." The new algorithm insures that once pre-paging is completed for such a background task, the task will receive its full 10-sec allotment of processor time before any of its files are written out regardless of the number of interactive users the system is supporting. That is, although such a user may be interrupted by highly interactive users, he will be allowed to run out his time slice before any other background user is given processor time.

Previously, when a background job was interrupted, its new position in the background queue was a function of the amount of processor time it had already used. As a consequence, the interrupted background job might be written out onto the drum to make room for the files required by other background tasks that had less running time and therefore had higher priority. It has been observed that the new algorithm reduces costly swaps. For the background user, it means the start of his job is delayed longer on the average, but once started takes less time to complete. All users, of course, benefit from the reduction in total amount of core-drum swapping.

Features have been incorporated which enhance the usefulness of the IBM tapes. Three new tape services are available: (a) a command that types on the console or Xerox printer a log of information about files on a tape, (b) a program that takes a user out of the system by writing out onto tape all his files and the other information contained in his directory, and (c) a command to reverse the process, i.e., to restore a user to the system.

### III. HUMAN INFORMATION PROCESSING

An approach to the study of both the integrative and inhibitory aspects of visual temporal processing was described in the previous Quarterly Technical Summary. It involves latencies in detecting stimuli that comprise two successive flashes. More recent analyses have indicated that the latency for a pair of suprathreshold flashes can sometimes be ascribed solely to the second, more-intense flash, even when the flash is presented as much as 50 msec after the first. The latency thus behaves as if the stimulus starts with the onset of the second flash. Furthermore, by increasing the intensity of the second flash, it has been possible to increase the range of interflash intervals over which the two flashes interact; however, increasing the duration of the second flash has had no such effect. The experimental analysis is being continued.

A new experimental apparatus for the study of human judgment behavior is being assembled. The equipment centers on a Digital Equipment Corporation PDP8/L computer which is to be used as a real-time control device, a stimulus generator, and a response choice and latency recorder. I/O equipment includes high-speed paper-tape punch and reader, digital-to-analog converters to drive a Type 611 Tektronix storage CRT, an external clock pulse generator, and miscellaneous input and output bit channels. Current efforts are concerned with wiring up the I/O channels and writing utility programs. The initial experiments will be concerned with a study of the rate of formation of recognition schema in making complex sensory judgments.

## COMPUTER SYSTEMS GROUP 28

### I. COMPUTER CENTER DEVELOPMENT

Previously, it was determined that a goal for the computer facility would be to increase the capabilities of the CP/CMS Time-Sharing System's batch processing facility to support the use of private tapes. A small committee has completed the design of the Batch Monitor System (BMS) to handle tape input/output. This involves modifications to the current BMS job control language to permit the specification of attached devices (i.e., tapes or disks) together with the parameters for describing the volumes to be mounted on a device. This SETUP specification will be made before a job is begun and verified by the I/O routines before the device is actually used. The job control language will consist of control and command statements (cards). The command statements will take the same form as the commands issued on-line to CMS.

Since BMS will run under CP, a rudimentary remote job entry (RJE) facility will also be provided. Remote job output (RJO) will only be provided in a limited way via virtual punched files.

In addition to the tape facility, improved and expanded routines will be added to handle I/O using assembly language macros similar to those provided by the OS/360 data management facility. The objective will be that, by changing control cards, Fortran and Assembly Language I/O programs will be able to run under either OS/360 or BMS.

Improvements made to the time-sharing system now permit teletypes to be used as on-line terminals. This capability also enables use of the Advanced Remote Display Station (ARDS), a storage tube graphical output device, as a terminal to CP/CMS. Work is also progressing on the support of the IBM 2260 Alphameric display device as a remote terminal. The addition of four 2260 terminals will bring the maximum number of simultaneous users of the time-sharing facility to 36.

In the CMS area, a command has been added which provides on-line information indicating the use of each CMS command. This on-line documentation supplements the written documentation. A number of other modifications have been made to CMS commands which facilitate file maintenance and manipulation.

As the work of maintaining IBM's OS/360 batch monitor continues, two other versions of this system are being tested. One of these, which could replace the present version for general use, is called the Houston Automatic Spooling Priority System (HASP) operating as a supplement to OS/360 Option 2: Multiprogramming With a Fixed Number of Tasks (MFT). The salient features of MFT/HASP are direct card input and printed or punched output together with the efficiencies of multiprogramming of batch operation. A major problem, however, is the requirement for an additional 100,000 bytes of main storage for system use. A significant number, if not a majority, of Lincoln users would have to alter their programs to relinquish that much space.

The other version of OS/360 under test is one that is operating under the time-sharing system. The primary intention here is to permit work on OS/360 itself and not to use it as a production batch processing facility.

## II. LISTAR (Lincoln Information Storage and Associative Retrieval System)

Programs for defining a new LISTAR file and for adding entries to an existing file have been completed. These programs, executed with the bulk INPUT/OUTPUT capability, make it possible to define new LISTAR files and then add substantive data entries either from the terminal or from files on the disk.

A format description for the MESH file for our current experimental data base was completed. It resides in the master file – the primary description file. The MESH descriptors will be used as a model for revising the master's description of itself. This is required in order that processing programs may be able to manipulate data files which are established in the new block format. It is that format which makes possible out-of-block referencing.

A provisional design for the implementation of cross-file relations has been chosen.

## RADAR DIVISION 4

### INTRODUCTION

The Radar Division conducts a General Research program to develop new radar components and techniques which appear useful in future systems. The activities for the period 1 May through 31 July 1969 consist of the development of new devices and techniques for solid state power generation and amplification, experimentation with precision timing components and the exploration of microwave acoustics (microsound) applications. Separate reports are issued on the RDT, PRESS, RSP, and MTI radar programs.

H. G. Weiss  
Head, Division 4



## DIVISION 4 REPORTS ON GENERAL RESEARCH

15 May through 15 August 1969

### PUBLISHED REPORT

#### Technical Note

TN No.

DDC No.

1969-31    The Mode Spectrum  
            of Avalanche Diodes

H. Berger

3 June 1969

DDC\*

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\* Not yet assigned.

## MICROWAVE COMPONENTS

### GROUP 46

#### I. INTRODUCTION

Group 46 contributes to the Laboratory program through direct participation in specific projects and through a program of general research which is closely related to the microwave needs of the Laboratory. Continuing programs are in the areas of microwave acoustics (microsound), diode-using devices, and timing technology. The solid state diode device work is being re-oriented to include theoretical studies of new devices and techniques which are beginning to be important in solid state power generation and amplification.

#### II. MICROSOUND

##### A. Transducer Fabrication

The electron beam technique for micromachining structures with dimensions beyond the diffraction limit of light (less than 1 micron) may be adequate for the fabrication of high-frequency microsound components. Eight commercial scanning electron microscopes were evaluated and one machine was selected which fulfills the functions of computer tape control, pattern generation, and the ordinary scanning electron microscope functions of viewing surfaces via the secondary emission of electrons. It is anticipated that, with the aid of the scanning electron microscope, transducers will be fabricated which operate in the S-band frequency range and that it will become feasible to view directly surface acoustic waves at high frequencies. This feature should be quite useful for evaluating the efficacy of waveguiding and focusing structures.

##### B. Acoustic Amplifiers

Several new acoustic amplifiers were assembled and electroacoustic interactions have been observed. The composite amplifier was analyzed and gain curves were obtained as a function of semiconductor donor densities, gap height, frequency, and drift field. We are currently attempting to resolve the differences between the theoretical expectations and the experimental results.

##### C. Guided Elastic Waves

A waveguide consisting of an overlay of rectangular cross section on a perfectly rigid substrate has been studied theoretically. There are three classes of modes, the lowest mode consisting of a substantially transverse shear motion. The frequency range over which only one mode can propagate depends on the height-to-width ratio of the guide and on the elastic properties of the material of which it is made. For typical values of the properties and a height-to-width ratio of 0.4, single-mode operation over a frequency range of more than 20 percent is predicted.

The efficacies of various metallic structures on piezoelectric substrates for converting wideband electrical signals into Rayleigh surface waves have been studied. Theoretical predictions have been obtained regarding the acoustic directivity of the transducers and their bandwidth.

### III. DIODE DEVICES

The experimental circuit work has been temporarily halted in favor of pursuing some theoretical investigations related to the performance of diodes as power source, both oscillators and amplifiers. Initial results of approximate computer calculations of the influence of thermal effects on high-power CW performance show electrical changes of as much as a factor of 2 for X-band diodes. Other investigations, including formulation of diode models and the determination of the sensitivity of parameters to geometry, are being pursued.

### IV. TIMING TECHNOLOGY

The purpose of this program is to apply remotely synchronized clocks and nanosecond pulse technology to the concept of one-way radar or DME.

Three cesium clocks are now available. Equipment is being set up for continuously recording the timing errors of any pair of clocks for up to a total of six clocks. It is expected that four clocks will be operating by the end of the next reporting period.

The breadboard experimental transmitter and receiving equipment is progressing well. It is expected that, during the next quarterly period, some multipath data using 20-nsec pulses will be taken using a transmitter and receiver located in the vicinity of Lincoln Laboratory.

## OPTICS DIVISION 5

### INTRODUCTION

This section summarizes the General Research efforts of Division 5 for the period 1 May through 30 July 1969. A complete presentation of the Optics effort may be found in the quarterly Optics Research Report and in the Semiannual Technical Summary and Quarterly Letter Reports to the Advanced Research Projects Agency.

A. L. McWhorter  
Head, Division 5

R. H. Kingston  
Associate Head

# DIVISION 5 REPORTS ON GENERAL RESEARCH

15 May through 15 August 1969

## PUBLISHED REPORTS

### Journal Articles\*

JA No.			
3299	Characteristics of a Single-Frequency Sealed-Off CO <sub>2</sub> Amplifier	R. J. Carbone	IEEE J. Quant. Electron. <u>QE-5</u> , No. 1, 48 (1969)
3389	Gain Saturation and Diffusion in CO <sub>2</sub> Lasers	C. P. Christensen <sup>†</sup> C. Freed H. A. Haus <sup>†</sup>	IEEE J. Quant. Electron. <u>QE-5</u> , No. 6, 276 (1969)
3476	Direct Observation of the Lorentzian Line Shape as Limited by Quantum Phase Noise in a Laser above Threshold	E. D. Hinkley C. Freed	Phys. Rev. Letters <u>23</u> , No. 6, 277 (1969)

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## UNPUBLISHED REPORTS

### Meeting Speeches<sup>‡</sup>

MS No.			
2582	Direct Observation of the Lorentzian Lineshape of a Laser Above Threshold	C. Freed E. D. Hinkley	1969 Device Research Conference, University of Rochester, 23-26 June 1969
2611	Self-Modulation in CO <sub>2</sub> Lasers	A. H. M. Ross C. Freed H. A. Haus <sup>†</sup>	

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\* Reprints available.

<sup>†</sup> Author not at Lincoln Laboratory.

<sup>‡</sup> Titles of Meeting Speeches are listed for information only. No copies are available for distribution.



## OPTICS AND INFRARED GROUP 53

The CO<sub>2</sub> laser radar program includes the experimental work associated with the high-power CO<sub>2</sub> laser radar system, some aspects of the experimental work associated with the IR tracking radiometer, and the supporting component research and development carried on concurrently with the systems work to provide components and information to both systems and other Laboratory programs. The supporting research is primarily concentrated on gas lasers, solid state detectors, tunable oscillators, and optical techniques and components.

Laser radar Doppler data have been obtained from retroreflector-equipped aircraft at ranges to 25 miles and at various altitudes. Beam pointing has been done by both slaving to the infrared tracker and a visible tracker following a beacon on the aircraft. A program of evaluating effects of atmospheric absorption and image degradation using both fixed and moving targets is also under way.

Preliminary results have been obtained in a set of experiments designed to measure various possible mechanisms that may affect the formation of Lamb dip in CO<sub>2</sub> lasers. In these experiments, a relatively high-power saturating laser is used to deplete the population of an amplifier in a fixed line. A weak colinear beam from a frequency-swept probing laser oscillating in various other transitions is used to detect the effect of the saturating laser upon the amplifier as a function of pressure.

Preliminary absorption experiments have been performed on the  $\nu_3$  band of SF<sub>6</sub> by detecting frequency-modulated radiation from a tunable Pb<sub>0.88</sub>Sn<sub>0.12</sub>Te diode laser after it had passed through the gas cell. Many absorption lines were resolved, corresponding to the various angular momentum states of the SF<sub>6</sub> molecule. Initial data show a resolution of better than 100 MHz. Further experiments will show the effects of changes in diode current modulation frequency and amplitude, as well as the gas cell temperature and pressure.

## ENGINEERING DIVISION 7

### INTRODUCTION

The principal support of the General Research program by the Engineering Division lies in the design and fabrication of devices and improved research facilities at the Haystack-Millstone complex, and in the development of microelectronics at our Integrated Circuit Facility.

In the quarterly period ending 31 July 1969, work continued at Haystack in upgrading the antenna drive system and its controls, as well as in refining the cryogenics in the receiver. At Millstone, a major revision of the secondary reflector and its feed is under way in order to make the system frequency-selective.

We look forward to occupying newly constructed facilities for much of the Integrated Circuit section during the next quarterly period. Meanwhile, research and development continue on materials for microelectronics, including the fabrication of components and semiconductors, custom metalization by evaporative techniques, and the development of new approaches to computer-aided circuit layout.

J. F. Hutzenlaub  
Head, Division 7

# DIVISION 7 REPORTS ON GENERAL RESEARCH

15 May through 15 August 1969

## UNPUBLISHED REPORT

### Journal Article

JA No.

3486

A Beam-Lead Substrate Package  
for a Six-Stage TTL Shift  
Register

F. Bachner  
R. A. Cohen  
R. Mountain  
R. E. McMahon

Accepted by Microelectronics  
and Reliability

## MECHANICAL ENGINEERING GROUP 71

### I. HAYSTACK CRYOGENICS

A superconducting magnet consisting of a main coil and three trim coils in a hyperco jacket has been completed and assembled. The magnet is to be a spare for masers Nos. 1 and 2. This unit is to be cooled in the closed cycle refrigerator prior to installation of the two masers.

### II. MILLSTONE

Manufacturing drawings are being received from Philco-Ford Corporation, Palo Alto, California, for a new frequency-selective subreflector and UHF monopulse feed assembly for the 84-foot-diameter Millstone tracker. These drawings are being used by Lincoln Laboratory to manufacture ground plane and spar attachment frames for preliminary dipole testing and mechanical interface checks prior to delivery of the final subreflector assembly.

The design has been finalized on the mounting of a shaft-position encoder on the elevation torque-tube axis; however, studies are continuing to determine the method and arrangement to be used in azimuth.

The azimuth cable-wrap hardware has been installed and delivery of the special coax cable is being awaited for completion and testing.

## CONTROL SYSTEMS GROUP 76

Extensive testing was completed of the hydraulic motors and variable displacement pumps proposed for upgrading the Haystack antenna power drives. This testing established considerable confidence in the reliability of these components with large overhauling inertia loads. Such loads are believed to be the cause of numerous failures in the motors presently installed. Satisfactory closed-loop operation was demonstrated of both rate and position loops with the new components and simulated inertia load. The new motor has a close-coupled tachometer which makes possible a tight velocity loop, a desirable feature never achieved in the existing configuration. Tentative plans call for the installation of the improved drive system in December 1969.



## MICROELECTRONICS GROUP 77

The development of materials during this period has been both basic and applied. Sputtered and electron-beam evaporated Nichrome (70% Ni/30% Cr) resistors are under investigation, and temperature coefficients as a function of various sputtering parameters are of particular interest.

Metalization in the form of air-isolated crossovers has been successfully applied to the beam lead substrate structures described in our last report. Larger or more complex air-isolated substrates having 400 to 800 crossovers are also under development for special breadboard-type substrates.

Another fabrication technique for beam lead substrates is under investigation using sheet photoresist to cover the apertures in ceramic substrates prior to the deposition of metalized beam leads. This approach offers several advantages over the previous method of filling the apertures with glass. A microwave circuit using a single apertured substrate has been fabricated using this technique, and aluminum beam leads in a six-stage shift register have also been produced with some success.

Custom metalization on commercial 12-gate arrays has been successfully applied. These array chips are purchased without the final interconnecting logic metalization, and with a dielectric coating about 7500 Å thick. After preparing suitable masks, vias are opened in the dielectric at appropriate locations and the interconnecting metalization is deposited using chromium as an adhesion layer and gold as a final layer.

Several microstrip circuits have been produced using RF sputtered tantalum resistor films and capacitors having silicon dioxide as the dielectric.

A development program on Impatt diodes has resulted in electrically good diodes having an oscillation frequency of 12 to 13 GHz. Packaging problems have prevented attainment of satisfactory power levels with these diodes to date.

Continuing work on surface wave transducer-type amplifiers has resulted in a completed unit that is currently under test.

Metal oxide semiconductor capacitors, having excellent surface states and pinhole-free dielectric for use in a memory program, have been developed recently.

Planar diodes and transistors have been developed and fabricated during this period as a preliminary step in the development of special devices and integrated circuits.

A number of multichip circuits have been assembled to test the yield problems associated with large assemblies. Multiplier networks with 20 to 30 complex integrated circuit chips have been successfully fabricated for the Surface Techniques Group (Group 62) and several storage-type networks employing metal oxide semiconductor arrays have also been successfully fabricated for a vocoder system.

Computer-aided layout techniques have been improved during this period with the acquisition of a digitizer. A relatively sophisticated program is under development to simplify the extraction of dimensions from layouts using the digitizer.

Continued work on the Mann plot program is in progress so that the Mann pattern generator expected in October will be quickly operational and able to handle complex masks.

A new contract to permit on-line data entry and limited use of the CIRCUS circuit analysis program is under way. This work should make computer-aided circuit analysis available to designers throughout the Laboratory, even if they are nonprogrammers.

## SOLID STATE DIVISION 8

### INTRODUCTION

This section summarizes the work of Division 8 from 1 May through 31 July 1969. A more detailed presentation is covered by the Solid State Research Report for the same period.

P. E. Tannenwald  
Acting Head, Division 8

# DIVISION 8 REPORTS ON GENERAL RESEARCH

15 May through 15 August 1969

## PUBLISHED REPORTS

### Journal Articles\*

JA No.			
3173A	Statistical Thermodynamics of Nonstoichiometry in Non-metallic Binary Compounds	R. F. Brebrick	J. Solid State Chem. <u>1</u> , 88 (1969)
3197	The ReO <sub>3</sub> Band Structure in the Tight-Binding Approximation	J. M. Honig J. O. Dimmock W. H. Kleiner	J. Chem. Phys. <u>50</u> , 5232 (1969)
3308	Conditions for Microwave Radiation from Excited OH $\Lambda$ -Doublet States	M. M. Litvak B. Zuckerman <sup>†</sup> D. F. Dickinson <sup>†</sup>	Astrophys. J. <u>156</u> , 875 (1969)
3329	Isolation of Junction Devices in GaAs Using Proton Bombardment	A. G. Foyt W. T. Lindley C. M. Wolfe J. P. Donnelly	Solid-State Electron. <u>12</u> , 209 (1969)
3340	Infrared Pumping of Interstellar OH	M. M. Litvak	Astrophys. J. <u>156</u> , 471 (1969), DDC AD-689902
3346	A New Series of Rare Earth Garnets $\text{Ln}_3^{3+}\text{M}_2\text{Li}_3\text{O}_{12}$ (M = Te, W)	H. M. Kasper	Inorg. Chem. <u>8</u> , 1000 (1969)
3394	Far Infrared and Submillimeter Impact Ionization Modulation	I. Melngailis P. E. Tannenwald	Proc. IEEE (Letters) <u>57</u> , 806 (1969)
3437	The Effect of Pressure and B-Cation Size on the Crystal Structure of CsBF <sub>3</sub> Compounds (B = Mn, Fe, Co, Ni, Zn, Mg)	J. M. Longo J. A. Kafalas	J. Solid State Chem. <u>1</u> , 103 (1969)
3447	Polymorphism in Selenospinel - A High Pressure Phase of CdCr <sub>2</sub> Se <sub>4</sub>	M. D. Banus M. C. Lavine	J. Solid State Chem. <u>1</u> , 109 (1969)
3463	Temperature and Compositional Dependence of Laser Emission in Pb <sub>1-x</sub> Sn <sub>x</sub> Se	T. C. Harman A. R. Calawa I. Melngailis J. O. Dimmock	Appl. Phys. Letters <u>14</u> , 333 (1969)

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\* Reprints available.

<sup>†</sup> Author not at Lincoln Laboratory.



Division 8

JA No.

3470	Spin Polarized Splittings in the Temperature Dependent Reflectance of EuO	J. Feinleib W.J. Scouler J. O. Dimmock J. Hanus T. B. Reed C. R. Pidgeon*	Phys. Rev. Letters <u>22</u> , 1385 (1969)
3474	Polaron Zeeman Effect in AgBr	R. C. Brandt D. M. Larsen P. P. Crooker G. B. Wright	Phys. Rev. Letters <u>23</u> , 240 (1969)
3475	Efficient Doping of GaAs by Se <sup>+</sup> Ion Implantation	A. G. Foyt J. P. Donnelly W. T. Lindley	Appl. Phys. Letters <u>14</u> , 372 (1969)
3497	New Electron Spin Waves in Nonmagnetic Conductors	F. A. Blum	Phys. Rev. Letters <u>23</u> , 73 (1969)
3507	Magnetic Field Dependence of Laser Emission in Pb <sub>1-x</sub> Sn <sub>x</sub> Se Diodes	A. R. Calawa J. O. Dimmock T. C. Harman I. Melngailis	Phys. Rev. Letters <u>23</u> , 7 (1969)
MS-2023	Electron Band Structure Studies Using Differential Optical Techniques and High Magnetic Fields	J. G. Mavroides	Chapter 8, <u>Physics of Solids in Intense Magnetic Fields</u> (Plenum Press, New York, 1969)
MS-2182	Fourier Expansion for the Deformation Potential in the Diamond Lattice	G. F. Dresselhaus M. S. Dresselhaus	} <u>Proc. 9th International Conference on Physics of Semiconductors</u> , Vol. 1 (1968)
MS-2291	Fourier Expansions for Dispersion Relations in Semiconductors	G. F. Dresselhaus	
MS-2304	Laser Action and Photodetection in Lead-Tin Chalcogenides	I. Melngailis	<u>Proc. International Colloquium on IV-VI Compounds</u> [J. de Physique <u>29</u> , C4-84 (1968)]
MS-2325	Thermal Brillouin Scattering Study of the Attenuation of Hypersound in Quartz	A. S. Pine	} <u>Light Scattering Spectra of Solids</u> , G. B. Wright, ed. (Springer-Verlag, New York, 1969)
MS-2333	Raman Scattering from Lattice Vibrations of GaAs <sub>x</sub> P <sub>1-x</sub>	N. D. Strahm A. L. McWhorter	
MS-2334	Landau Level Raman Scattering	G. B. Wright P. L. Kelley S. H. Groves	

\* Author not at Lincoln Laboratory.

JA No.			
MS-2340	Tin Doping of Epitaxial Gallium Arsenide	C. M. Wolfe G. E. Stillman W. T. Lindley	<u>Proc. 1968 Symposium on GaAs</u> (Institute of Physics and The Physical Society, 1969)
MS-2349	Deviations from Stoichiometry and Lattice Defects in IV-VI Compounds and Their Alloys	A. J. Strauss R. F. Brebrick	J. de Physique (Supp.) <u>29</u> , C4-21 (1968)
MS-2362A	The High Pressure Forms of CsNiF <sub>3</sub>	J. M. Longo J. A. Kafalas	J. Appl. Phys. <u>40</u> , 1601 (1969)
MS-2374	Distant-Neighbor B-B Interactions in Cobalt Chromite	K. Dwight N. Menyuk	J. Appl. Phys. <u>40</u> , 1156 (1969)
MS-2377	Some Critical Properties of Quantum-Mechanical Heisenberg Ferro- and Antiferromagnets	H. E. Stanley	J. Appl. Phys. <u>40</u> , 1546 (1969)
MS-2378A	Exact Solution for a Linear Chain of Isotropically-Interacting Classical Spins of Arbitrary Dimensionality	H. E. Stanley	Phys. Rev. <u>179</u> , 570 (1969)
MS-2380	Pressure Effect Measurements Using a Vibrating-Coil Magnetometer	N. Menyuk J. A. Kafalas K. Dwight J. B. Goodenough	J. Appl. Phys. <u>40</u> , 1324 (1969)
MS-2384	Band Structure of Magnetic Semiconductors	D. Adler J. Feinleib	J. Appl. Phys. <u>40</u> , 1586 (1969)
MS-2385	Optical Studies and Band Structure of Cu-Ni Alloys	J. Feinleib W. J. Scouler J. Hanus	J. Appl. Phys. <u>40</u> , 1400 (1969)

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## UNPUBLISHED REPORTS

Journal Articles

JA No.			
3429A	Avalanche Breakdown and Light Emission at Low-Angle Boundaries in n-ZnSe	J. P. Donnelly F. T. J. Smith	Accepted by Solid State Electron.
3444	Derivation of a Quasiparticle Transport Equation for an Impure Fermi Liquid at Low Temperatures	J. L. Sigel	Accepted by Phys. Rev.
3483	X-ray Diffraction Studies on Cd <sub>3</sub> As <sub>2</sub> and Zn <sub>3</sub> As <sub>2</sub> at High Pressure	M. D. Banus M. C. Lavine	Accepted by High Temperatures-High Pressures

Division 8

JA No.

3485	Velocity and Attenuation of Hypersonic Waves in Liquid Nitrogen	A. S. Pine	Accepted by J. Chem. Phys.
3490	OH and H <sub>2</sub> O Masers in Protostars	M. M. Litvak	Accepted by Science
3491	Perturbation of the Refractive Index of Absorbing Media by a Pulsed Laser Beam	P. R. Longaker M. M. Litvak	Accepted by J. Appl. Phys.
3498	Polarons Bound in a Coulomb Potential. 1. Ground State	D. M. Larsen	Accepted by Phys. Rev.
3503A	Millimeter Wave Emission by Interstellar Dust	M. M. Litvak	Accepted by Nature
3541	Magnetic Ordering Effects on the Reflectivity of EuS and EuSe	C. R. Pidgeon* J. Feinleib W. J. Scouler J. Hanus J. O. Dimmock T. B. Reed	Accepted by Solid State Commun.
3548	A Conceptual Phase Diagram for Outer Electrons in Solids	J. B. Goodenough	Accepted as a chapter in <u>Current Topics in Magnetism</u> (Gordon and Breach, New York)
MS-2466	The Role of Oxygen Pressure in the Control and Measurement of Composition in 3d Metal Oxides	T. B. Reed	Accepted by J. Solid State Chem.
MS-2506	Structural, Electrical and Magnetic Properties of Vacancy Stabilized Cubic 'TiO' and 'VO'	M. D. Banus T. B. Reed	Accepted by J. Solid State Chem.
MS-2515	Evidence for a Continuous Sequence of Phases in the Bi-Te System	R. F. Brebrick	Accepted by J. Solid State Chem.

Meeting Speeches<sup>†</sup>

MS No.

2349A,B	Deviations from Stoichiometry in IV-VI Compounds and Their Alloys	A. J. Strauss	Seminar, University of Pennsylvania, 21 May 1969; Summer Course, M.I.T., 1 July 1969
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\* Author not at Lincoln Laboratory.

† Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

MS No.			
2466A	Stoichiometry of 3d Metal Oxides as a Function of Oxygen Pressure	T. B. Reed	} Seminar, Purdue University, 20-21 May 1969
2496A	Pitfalls, Detours and Shortcuts on the Road to Single Crystal Growth	T. B. Reed	
2482A	Shubnikov-deHaas Measurements in $\text{Pb}_{1-x}\text{Sn}_x\text{Te}$	J. Melngailis	Seminar, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 23 May 1969
2500	Spark Source Mass Spectroscopy	E. B. Owens	22nd Annual Summer Symposium on Analytical Chemistry, University of Georgia, 11-13 June 1969
2528A	Light Scattering Experiments at 1.06 Microns	A. Mooradian	} Conference on Short Laser Pulses and Coherent Interactions, Chania, Crete, Greece, 13-26 July 1969
2608	Semiconductor Lasers	I. Melngailis	
2528C	Light Scattering Experiments at 1.06 Microns	A. Mooradian	} Gordon Research Conference, Quantum Solids and Fluids, Providence Heights College, Issaquah, Washington, 21-25 July 1969
2617	One-Electron Theory of Interband Transitions	G. F. Dresselhaus	
2545	High Pressure Phases with Perovskite Related Structure in the System $\text{Sr}_{1+x}\text{IrO}_{3+x}$ ( $x = 0, 1/3, 1/2, 1$ )	J. A. Kafalas J. M. Longo	8th International Congress of Crystallography, State University of New York, 14 August 1969
2549	Photoresponse Properties of InSb MOS Devices	W. E. Krag R. J. Phelan J. O. Dimmock	} 3rd International Conference on Photoconductivity, Stanford University, 12-15 August 1969
2551	Donor Magnetospectroscopy in High Purity Epitaxial GaAs	G. E. Stillman C. M. Wolfe J. O. Dimmock	
2575	Quantitative Analysis of Ternary and Quaternary Semiconducting Alloys	M. C. Finn	4th National Conference on Electron Microprobe Analysis (Electron Microprobe Society of America), Pasadena, California, 16-18 July 1969
2580	Tunable Long-Wavelength Infrared $\text{Pb}_{1-x}\text{Sn}_x\text{Se}$ Diode Lasers	A. R. Calawa I. Melngailis J. O. Dimmock T. C. Harman	} Device Research Conference, University of Rochester, 23-26 June 1969
2581	MIS Electroluminescent Diodes in ZnTe	J. P. Donnelly A. G. Foyt W. T. Lindley	



Division 8

MS No.

2583	Extrinsic GaAs Photodetectors for the 100-400 $\mu$ Region	G. E. Stillman C. M. Wolfe J. O. Dimmock	Device Research Conference, University of Rochester, 23-26 June 1969
2589	Interstellar Molecules	M. M. Litvak	Seminar, M. I. T., 16 May 1969
2590	Phase Diagrams and Crystal Growth of CdTe-ZnTe, CdTe-CdSe, and ZnTe-ZnSe Alloys	J. M. Steininger A. J. Strauss	Conference on Crystal Growth, Gaithersburg, Maryland, 11-13 August 1969
2594	Growth of EuO, EuS, EuSe, and EuTe Single Crystals	T. B. Reed R. E. Fahey	
2595	Film: Arc Crystal Growth and Other Arc Materials Techniques	T. B. Reed M. D. Banus	
2598	Theory and Practice of Vapor Phase Crystal Growth	T. B. Reed	
2599	The Hartree-Fock Approximation	T. A. Kaplan	Seminar, M. I. T., 23 May 1969
2600	Maser Properties of Interstellar Molecules	M. M. Litvak	Joint Astrophysics and Center for Fluid Dynamics Seminar, Brown University, 27 May 1969
2609	Resistivity and Hall Effect (Technique and Interpretation)	A. J. Strauss	Summer Course, M. I. T., 1 July 1969
2625	Non-Equilibrium Processes Related to Interstellar Molecules	M. M. Litvak	Summer Course, M. I. T., 10 July 1969
2625A	Non-Equilibrium Processes Related to Interstellar Molecules	M. M. Litvak	Summer Institute, Brandeis University, 15 July 1969

## SOLID STATE DIVISION 8

### I. SOLID STATE DEVICE RESEARCH

The temperature dependence of the energy of laser emission from  $\text{Pb}_{1-x}\text{Sn}_x\text{Se}$  diodes in the composition range  $0 \leq x \leq 0.3$  has been studied at temperatures up to  $100^\circ\text{K}$ . For  $0 \leq x < 0.15$ , the temperature dependence is positive and equal to  $+5.0 \times 10^{-4} \text{ eV}/^\circ\text{K}$  above  $30^\circ\text{K}$ , whereas for  $0.15 < x \leq 0.3$  the temperature coefficient is negative and about the same magnitude. This is consistent with the band model proposed in which the conduction and valence bands invert and exchange roles at about  $x = 0.15$  at low temperatures.

In addition, the magnetic field dependence of the energy of laser emission from  $\text{Pb}_{1-x}\text{Sn}_x\text{Se}$  diodes in this composition range has been studied at  $4.2^\circ\text{K}$  in magnetic fields up to  $145 \text{ kG}$ . For  $0 \leq x < 0.15$ , the magnetic field dependence is positive for all emission lines observed and is equal to about  $+1.0 \times 10^{-7} \text{ eV/G}$  for the lowest energy line. For  $0.15 < x \leq 0.3$ , this coefficient has about the same absolute value but is negative. This is again consistent with the proposed band inversion model. The magnetic field data have been used to obtain information not only on the extremal conduction and valence bands but on the other bands in the vicinity of the energy gap as well.

Total ionized impurity densities from  $7 \times 10^{13}$  to  $3 \times 10^{17} \text{ cm}^{-3}$  have been determined for epitaxial samples of n-type GaAs by analyzing mobility and carrier concentration data as a function of temperature using the Brooks-Herring formula for ionized impurity scattering. The procedure employed minimizes the effects of other scattering mechanisms and gives results which are in good agreement with impurity densities obtained from analyses of the temperature variation of the Hall constant. These results have been used to determine empirical curves relating the impurity density to the  $77^\circ\text{K}$  Hall mobility and carrier concentration measured at  $5 \text{ kG}$ .

The effect of donor concentration on the extrinsic photoconductivity spectra of shallow donors in GaAs has been studied for donor concentrations between  $4.8 \times 10^{13}$  and  $2 \times 10^{15} \text{ cm}^{-3}$ . The photoconductivity peak corresponding to the impurity ground state to first excited state transition remains essentially constant at  $4.41 \text{ meV}$ , while the measured thermal ionization energy decreases from  $5.52$  to  $3.29 \text{ meV}$  over this same concentration range. The change in thermal ionization energy is thus attributed to the merging of the higher excited impurity states with the conduction band edge rather than to a shift in the ground state energy.

Spectral measurements have been made on electroluminescent metal-insulator-semiconductor (MIS) diodes fabricated from p-type ZnTe. The insulating region was created by proton bombardment, and gold was used for the metal contact. Both green and red electroluminescence was observed in devices made from different crystals. The green electroluminescence is associated with the bandgap and has a quantum efficiency of  $2 \times 10^{-4}$  at  $300^\circ\text{K}$  and  $10^{-3}$  at  $77^\circ\text{K}$ . The red electroluminescence is associated with an isoelectronic trap due to oxygen impurities and has a quantum efficiency of  $3 \times 10^{-3}$  at  $300^\circ\text{K}$  and  $4 \times 10^{-3}$  at  $77^\circ\text{K}$ .

## II. MATERIALS RESEARCH

Single crystals of EuO, EuS, EuSe, and EuTe up to 2 cm on a side have been grown by slow cooling of Eu-rich solutions (or nominally stoichiometric melts, for EuO) in sealed tungsten crucibles. Thermal analysis has been used to determine the congruent melting point of EuO (2015°C).

Single crystals of NbO have been grown by pulling from the melt in a tri-arc furnace. The limits of the homogeneity range of  $\text{NbO}_x$  are approximately  $x = 0.98$  and  $x = 1.02$ , and the congruently melting composition is  $x = 1.006$ .

The phase diagram of the CdTe-CdSe pseudobinary system has been determined by thermal analysis and x-ray diffraction measurements. Below the solidus curve, the diagram consists of Te- and Se-rich regions of alloys with zinc-blende and wurtzite structure, respectively, separated by a narrow two-phase region whose boundaries are strongly temperature dependent.

The Hall coefficient and resistivity of undoped CdSe single crystals have been measured at temperatures up to 950°C and at controlled cadmium vapor pressures between 100 and 700 torrs. Over the pressure range investigated, the results show that above 600°C the electrical properties are determined by the concentration of a doubly ionized native donor defect.

A large number of germanates and stannates with the  $\text{PbSb}_2\text{O}_6$  structure have been prepared by sintering stoichiometric mixtures of oxides and carbonates. The optical properties of  $\text{MnGeTeO}_6$  indicate that this compound contains, in addition to  $\text{Mn}^{2+}$ , a small amount of  $\text{Mn}^{4+}$  substituted for  $\text{Ge}^{4+}$ .

An x-ray diffraction study of  $\text{MnSb}_2\text{O}_6$  has shown that this compound has a structure closely related to that of  $\text{Na}_2\text{SiF}_6$ , rather than the niobite structure reported previously. Data for a number of other oxides indicate that these also have structures related to the  $\text{Na}_2\text{SiF}_6$  structure.

The relationship between structure and physical properties of the  $\text{M}_x\text{V}_2\text{O}_5$ - $\beta$  phases ( $\text{M} = \text{Cu}, \text{Li}, \text{Hg}, \text{Na}, \text{Ag}$ ) has been re-examined. The analysis, together with small polaron theory, gives an expression (containing no adjustable parameters) which is in excellent agreement with experimental data for the Seebeck coefficient as a function of  $x$ .

The first three atomic form factors of Ni have been determined by means of absolute x-ray intensity measurements on pressed powders. The results agree within experimental error with a set of published values obtained in transmission experiments on thin single crystals, rather than with a set obtained in earlier measurements on powders.

X-ray diffraction measurements at room temperature with diamond anvil cameras have shown that  $\text{Cd}_3\text{As}_2$  and  $\text{Zn}_3\text{As}_2$  transform at high pressures to similar trigonal phases. The high-pressure phase of  $\text{Cd}_3\text{As}_2$  could be retained at atmospheric pressure by cooling to low temperature before releasing the pressure, but this was not the case for  $\text{Zn}_3\text{As}_2$ .

Magnetic and optical measurements have been made on the atmospheric- and high-pressure forms of  $\text{CsCoF}_3$ . The former exhibits antiferromagnetic ordering below 8°K, while the latter undergoes a ferrimagnetic transition at 50°K.

In order to improve the precision of chemical analyses which use EDTA titrations with color change end points, a method has been developed for performing these titrations automatically. In initial experiments on the determination of zinc, this automatic photometric method has achieved the same precision as a standard method employing automatic potentiometric titration.

### III. PHYSICS OF SOLIDS

A comprehensive magneto-optical study of the conduction band of InSb has been carried out. Aside from the fundamental cyclotron resonance transitions, additional transitions involving impurities, spin-flip, cyclotron resonance harmonics and phonons were investigated.

Electron-phonon interactions were also investigated in CdTe with cyclotron resonance measurements at discrete laser and carcinotron wavelengths between 118 and 901  $\mu$ . The effective mass of the polarons was found to vary in the manner predicted from a variational calculation of the lowest Landau level energies.

Although the necks in the Fermi surface of copper have been clearly detected by positron annihilation studies, there is an apparent disagreement concerning the size of the necks as measured by various slit geometries. A single noninteracting particle calculation of the expected increase in the counting rate gives an estimate which is a factor of two smaller than the rectangular slit measurement, and somewhat larger than that of the point slit result.

The band structure study of magnetic semiconductors has now been extended to EuS and EuSe. Measurements as a function of temperature of the reflectivity of the peak associated with the fundamental absorption edge of these materials, using circularly polarized light and an orienting magnetic field, indicate a behavior similar to that of EuO and support the model proposed for the latter ferromagnetic semiconductor.

A new type of electron spin waves in nonmagnetic conductors has been predicted. These waves, which can exist even when explicit exchange interactions are unimportant, arise from spin-orbit coupling and the long-range self-consistent field of the electrons.

Fine structure, which is a manifestation of an allowed linear dependence of the optical phonon frequency with wavevector, has been observed in the low-temperature Raman spectrum of the  $128\text{-cm}^{-1}$  E-mode in  $\alpha$ -quartz. The optical activity which should be associated with this linear wavevector shift has been calculated.

A general calculation (which includes particle-particle Coulomb interactions, band structure of arbitrary nature, and virtual interband processes) has been made of the cross section for inelastic scattering of light from carriers in semiconductors placed in a magnetic field. The results encompass scattering from the longitudinal magnetoplasma collective modes, single-particle excitations between Landau levels and spin states, spin density fluctuations, and spin waves.



DOCUMENT CONTROL DATA - R&D		
(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)		
1. ORIGINATING ACTIVITY (Corporate author)  Lincoln Laboratory, M.I.T.		2a. REPORT SECURITY CLASSIFICATION Unclassified
		2b. GROUP None
3. REPORT TITLE  General Research Quarterly Technical Summary		
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Quarterly Technical Summary for 1 May through 31 July 1969		
5. AUTHOR(S) (Last name, first name, initial)  Frick, Frederick C.      Kingston, Robert H.      McWhorter, Alan L. Weiss, Herbert G.      Hutzenlaub, John F.		
6. REPORT DATE 15 August 1969	7a. TOTAL NO. OF PAGES 48	7b. NO. OF REFS None
8a. CONTRACT OR GRANT NO. AF 19(628)-5167	9a. ORIGINATOR'S REPORT NUMBER(S) General Research QTS for 15 August 1969	
b. PROJECT NO. 649L	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) ESD-TR-69-210	
c.		
d.		
10. AVAILABILITY/LIMITATION NOTICES  This document has been approved for public release and sale; its distribution is unlimited.		
11. SUPPLEMENTARY NOTES  None	12. SPONSORING MILITARY ACTIVITY  Air Force Systems Command, USAF	
13. ABSTRACT  <p>This Quarterly Technical Summary covers the period from 1 May through 31 July 1969. It consolidates the reports of Division 2 (Data Systems), Division 4 (Radar), Division 5 (Optics), Division 7 (Engineering), and Division 8 (Solid State) on the General Research Program at Lincoln Laboratory.</p>		
14. KEY WORDS  data systems      control research      microwave equipment digital computers      radio physics      mechanical and structural engineering computer components      space surveillance      solid state physics psychology      radar		